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REPORT NO M 9-76

EFFECTS OF PRIOR HYPOXIA EXPOSURE ON VISUAL TARGET DETECTION DURING LATER MORE SEVERE HYPOXIA AND NOTE ON THE RELATIONSHIP BETWEEN INTROVERSION-EXTRAVERSION FIELD-DEPENDENCE-INDEPENDENCE, & ACCURACY OF VISUAL TARGET DETECTION

U S ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE

Natick, Massachusetts

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MEDICAL RESEARCH & DEVELOPMENT COMMAND

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Report #2 - Same as #1 plus: Introversion - extroversion; field dependence-independence.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

SUMMARY - "Effects of Prior Hypoxia Exposure..." Three groups of 15 subjects each were exposed to 3 different combinations of intermediate (staging) altitudes and exposure times, and were then tested for visual target detection capability at a final altitude of 4300 meters. All groups with staging exposure performed better at altitude and had fewer symptoms of acute mountain sickness than a fourth group which went directly

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to 4300 meters altitude from sea level. The data showed that task factors of both viewing distance and degree of peripheral target placement significantly influenced detection time within all groups regardless of altitude exposure variations

REPORT #2 - "Note on the Relationship..."

Field-dependence-independence (Hidden Shapes Test) and extraversion-introversion (Maudsley Personality Inventory) were found to be separately and jointly related to accuracy of target detection. The major effects were attributable to the notably poorer performance of Ss characertized as field-dependent extraverts.

Effects of Prior Hypoxia Exposure on Visual Target Detection During Later More Severe Hypoxia

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The effects of sudden exposure to elevations of 3000 - 5200 meters (9800 - 17,000 feet, approximately) has been well-documented (VanLiere and Stickney, 1963), and includes acute mountain sickness (Singh, et al., 1969), decreased work capacity (Balke, et al., 1956), and impaired intellectual function (McFarland, 1937). Other findings, comprehensively reviewed by Tune (1964), have shown that hypoxia also produces significant decrements among a wide range of visual capacities, including dark adaptation (McFarland and Halperin, 1940), brightness discrimination (Hecht, et al., 1946), color sensitivity (Frantzen and Iusfin, 1958; Kobrick, 1970; Schmidt and Bingel, 1953), ocular muscle balance (Masters, 1964), and flicker sensitivity (Berg, 1955). More recently, Kobrick (1965, 1971, 1972), Kobrick and Appleton (1971), and Kobrick and Dusek (1970) have shown that hypoxia impairs sensitivity for detecting light flash stimuli in the peripheral visual field; this impairment is directly related to the degree of peripheral stimulus placement and to the severity of hypoxia exposure.

Numerous approaches for mitigating the effects of altitude exposure have been taken, and the technique of prior exposure to a moderate elevation, as a sort of pre-adaptation, shows some promise. In fact, temporary

residence (one week or longer) at an intermediate altitude before subsequent exposure to a more severe altitude has been traditionally used by mountaineering expeditions, in experimental studies (Balke, et al., 1956; Balke and Wells, 1958; Hansen, et al., 1967), and by the Indian Army in acclimating its troops to high altitude (Roy and Singh, 1967). However, the specific degree of benefit produced by different exposure periods at lower altitudes prior to ascent is unknown. Also, the effects of such altitude staging upon eventual visual perceptual capability has not been determined. Since hypoxia results in systematic impairment of peripheral visual sensitivity for response to a stimulus as esoteric as a simple light flash, then one might expect similar impairment to more perceptually demanding stimuli occurring in the visual periphery, such as detection of significant terrain features, or military targets. Staging could, in turn, be expected to mitigate such hypoxic impairments as might occur.

During a recent military field study*, an opportunity was provided to examine the effects of staging at low altitudes on subsequent peripheral viewing capability at a higher altitude. In this exercise, control measurements were first obtained at San Antonio, Texas, (200 m) on a variety of tests ranging through physical fitness measures, physiological and medical indices, symptom profiles, and various performance measures. As part of this test battery, a target detection task was administered, and is the specific subject of this paper. This task consisted of projected slides

* Conducted by the U.S. Army Research Institute of Environmental Medicine, Natick, MA 01760, in 1973.

depicting a rifleman in kneeling firing stance seen at various locations across the field of view, and at several different viewing distances. The soldier subjects were then exposed to various staging altitudes, and comparative performance measures on the task were subsequently obtained at 4300 m altitude. This paper reports the effects of the prior hypoxia exposures involved upon visual detection of peripheral targets during the later-experienced hypoxia level.

Method

Subjects

Sixty young male soldiers were used, and were divided into 4 groups of 15 each. Their performance was voluntary, and included a signed consent form to that effect. They were screened for normal vision (20/20 correctable acuity), and for physical disorders which might be aggravated by hypoxia. The physically qualified subjects then completed an 8-hour exposure to a simulated altitude of 4300 meters in a hypobaric chamber (Brooks Air Force Base, Texas) to assess their altitude tolerance and observe any illness symptom profiles which might occur. They were then assigned to the main experiment.

Apparatus and Procedure

The visual target detection task consisted of viewing a series of 72 35 mm (2 x 2) Ektachrome-X color slide transparencies depicting an infantry soldier dressed in O.G. combat uniform with helmet kneeling in firing position aiming an Army M-16 rifle at the camera. He was seen across

a field against a background of trees and brush. The scene was created by positioning the soldier along lines of sight which subtended selected fixed angles to both right and left of a hypothetical mid-line at the center of the field of view (see Figure 1).

Figure 1 about here

In this manner, a set of 8 slides was obtained for a given viewing distance; namely, center, 7° right, 14° right, 21° right, 7° left, 14° left, 21° left, and a "blank" slide consisting only of the background with no target present. Furthermore, the slides at all viewing distances contained targets within the same maximum possible extent to the periphery, since their positions were determined by the same angular deviations from center at each distance. Thus, the potential scanning requirement for target location was equated in all slides regardless of the viewing distance. The slides were made with a Nikon F 35 mm camera, equipped with a 60 mm wide-angle lens to reduce spherical optical distortion of the edge of the effective view. The camera was mounted on a tripod 5 feet above ground level (slightly less than the eye-height of a typical observer). A set of the 8 slides was obtained for each of 9 viewing distances (75', 100', 125', 150', 175', 200', 225', 250', 275'), with the camera sighting along the mid-line of the viewing field. The photography was performed on a sunny day (luminance approximately 1000 foot-lamberts).

The target detection task was administered with the subject seated facing a 6' x 8' lenticular projection screen, such that his eyes were 6 feet distant from its vertical surface. At this position, the screen filled his effective field of view. The slides were displayed with a Kodak Carousel projector equipped with a Kodak Ektanar f3.5 zoom lens mounted on a tripod at a projection distance of 20 feet and at a 5 foot height from the floor (the original camera height at which the slides were made). At this position, the projected image on the screen duplicated the actual image size of the soldier in the original scene at each viewing distance, the projected scene filled the visual field of the subject, and the scene was unobstructed by the subject's head. A schematic diagram of the apparatus set-up is shown in Figure 2.

Figure 2 about here

The slide set was presented in randomized order at a standard occurrence rate of 30 seconds per slide, with a 5-second interval between slides during which the screen was blank. An electronic timer was actuated at the appearance of each slide by an automatic programming device, and was stopped by the subject pressing a hand-held switch each time he located a target. All subjects were first given instruction and practice in performance of the task, during which they were told where the targets would be located, were shown a diagram identifying these positions, and learned standard

location names for them; i.e., "21 left", "7 right", "blank", etc. In each trial (slide occurrence), they were trained to identify the target position, and then to estimate its apparent distance from them (range). Unlocated targets received a response time (RT) score of 30 seconds.

The 4 groups of subjects each received different altitude exposure treatments, involving exposure to various intermediate altitude (staging) levels; all groups later received exposure to the same higher altitude at which final testing was done. A summary of the altitude treatments is given in Table 1. The altitudes involved were: 200 meters (sea level) -

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Table 1 about here

Fort Sam Houston, Texas; 1600 meters - Denver, Colorado; 3000 meters - Leadville, Colorado; 4300 meters - USARIEM High Altitude Research Facility, Pikes Peak, Colorado. All groups first received training and several practice trials within the time available during the sea level altitude condition. The complete slide series was presented at the original luminance (1000 ftL), and again with a neutral density filter over the projector lens which attenuated the luminance of the scene so as to simulate near-dusk viewing conditions (approximately 5 ftL). The task was administered at this reduced luminance because of the known influence of hypoxia on brightness sensitivity. The last complete series of scores

available at each luminance for each subject was used as the sea level base-line sample for comparison with later performance at the final altitude. The slides were arranged in different randomized orders in successive presentations to all subjects to minimize spurious cues to target location. In effect, all groups received one week of sea-level exposure for training and base-line performance measurement, and all then eventually received 4 days of exposure to the highest altitude. The group treatments differed in the amount and distribution of intermediate altitude exposure. Thus, Group 1 went directly from sea level to the highest altitude, and should represent the most severe altitude exposure condition, against which other group comparisons should be made. Group 2 received 4 days at 3000 meters before the final altitude; Group 3, 4 days at 1600 meters; Group 4, 2 days at 3000 meters. Because of time limitations in the testing schedule, each subject could only be tested twice during the 4-day exposure to 4300 meters altitude. In order to spread any altitude effects across the measured group performance of the representative groups, one-half of each group was tested on Days 1 and 3, the other half on Days 2 and 4. No performance measures were taken during the intermediate staging altitude exposures for any of the groups.

Results and Discussion

The data obtained for each subject consisted of response time (RT) to acquire the target, specification of the target location, and range estimation. These scores were available for both bright and dim viewing at both sea level (SL) and 4300 meter (ALT) exposure conditions. An

inspection of the range estimation data showed the values to be highly variable and erratic, both for individual subjects and for group means of the individual scores at all viewing distances. Also, the degree of variability appeared to be about the same for both the SL and ALT scores. In other words, the subjects did no better at near than at far viewing distances, and showed no discernible trends which could be tied to hypoxic stress. Also, if any trends were present in the data, they were probably obscured by the high subject variabilities. Therefore, analysis of the distance estimation data was judged to be of little value and was discontinued.

The SL and ALT RT data were first sorted to eliminate scores for target which were incorrectly identified, since responses to other than real targets were considered irrelevant to the interests of this study. The remaining values still amounted to a sizable group of data, and apparently the majority of responses were to real stimuli. Since different subjects had been tested on different days at altitude, analysis of the altitude effects on performance could legitimately be based only on overall group measures rather than on individual scores. Therefore, the daily data were pooled for each group, and statistical analysis was conducted using the resulting group mean values. These group means were first plotted for each target position as a function of viewing distance for each group at both SL and ALT for both bright and dim viewing in each case. It became clear that a detailed breakdown such as this was not

practical, in view of the variability inherent in the data. Since the curves for individual target positions crossed over and merged so much with each other, any systematic trends due to staging or ALT effects were obscured by the variability of subject performance. Nevertheless, it was still possible that ALT and staging could produce overall effects which might not be displayed consistently by responses to target positions but might be shown by a combined measure. Accordingly, the data were further collapsed into 2 basic sets of overall group means, one set for RT's for each viewing distance averaged across all target positions, the other set for each target position averaged across all viewing distances. These values were then plotted for bright and dim viewing separately, comparing SL and ALT performance for each group by itself. It was clear that some impairment of performance was produced by reduced luminance at both SL and ALT in all 4 groups. However, such reductions were present to about the same degree at both SL and ALT, and included a number of inversions and cross-overs among the curves. Thus, although some changes were produced by dim viewing conditions, they were obviously not associated with altitude in any systematically direct way, and were not considered to be sufficiently strong or pertinent to the interests of this study to be presented separately. However, since some differences between bright and dim viewing performance did occur, future work should probably consider a more sensitive test of the effect of altitude on brightness sensitivity factors in target detection.

Inasmuch as the bright-dim viewing distinction was not very large, the values were combined into a final set of overall means representing RT performance of the 4 groups under SL and ALT conditions. These values are presented graphically as Figures 3-10, in which Figures 3-6 show group mean RT for each viewing distance averaged across all target positions, and Figures 7-10 show group mean RT for each target position averaged across all viewing distances.

Figures 3 - 10 about here

In Figures 3-6, it is clear that RT increased markedly with viewing distance; i.e., smaller target objects were harder to see and took longer to find. However, this effect changed abruptly beyond 200 feet, where performance improved greatly in all 4 groups. Since this change is dramatically evident for 60 subjects who represented 4 independently drawn groups measured separately at different times, it was reasonable to suspect as the cause some physical attribute of the viewing situation common to all subject measurements. A re-examination of the test slides revealed that the slope of the terrain on which the camera was positioned appeared to rise moderately at about the 225 foot viewing distance, just where the improvement began to occur in the data. Such a rise in the ground could very likely confer an advantage to target location such as one gains from an elevated vantage point like a hill or tree in viewing a scene. This

could have made the targets easier to find by placing them in better perspective and contrast with the background than would have been the case at lower ground level. Even so, the viewing distance effect is certainly dramatic up through the 200 foot point. More important, however, is the clearly evident effect of prior staging on later performance at higher altitude. It can be seen, even through the inversion in trend for distances beyond 200 feet, that the RT performance of Group 1 (Figure 3) was poorer at ALT than at SL, whereas the opposite was true for Groups 2-4 (Figures 4-6). In other words, Groups 2-4 improved their performance with continued opportunity to practice, while Group 1 showed no change, and in fact became worse with the same amount of practice. Since Group 1 was the only one which went directly to ALT from SL, it seems clear that staging had a beneficial effect on performance by cancelling the effects of hypoxia and in effect allowing performance to improve. In order to evaluate the statistical significance of these SL-ALT differences, one-way analysis of variance tests were applied separately to the data of each group for the various viewing distances averaged across target positions (Figures 3-6). The differences for Groups 2, 3, and 4 were all highly significant ($P<.001$) (Group 2 - $F = 13.39$, $df = 35, 232$; Group 3 - $F = 15.65$, $df = 35, 230$; Group 4 - $F = 15.06$, $df = 35, 231$), indicating that staging did in fact facilitate a performance improvement, compared to Group 1, whose differences were not significant ($F = 0.98$, $df = 35,229$) and showed some indication of a performance decrement as well.

These same group differences appear even more clearly in Figures 7-10. The same one-way analysis of variance was also applied separately in the same manner for each group for target positions averaged across all viewing distances. Here the main effects were all highly significant ($P<.001$) (Group 1 - $F = 4.66$, df = 27,219; Group 2 - $F = 2.54$, df = 27,222; Group 3 - $F = 3.53$, df = 27,220; Group 4 - $F = 2.12$, df = 27,220). When the data are considered in this manner, then, it is clear that staging allowed significant performance improvements in all cases (Groups 2-4), whereas Group 1 became significantly poorer in performance. Thus, it would appear that even though target distance was a significant factor in the viewing situation influenced by hypoxia, the peripheral displacement of the target toward the edge of the field of view was even more significantly influenced by hypoxia. These results are quite consistent with the earlier findings of Kobrick* regarding the impairment of peripheral visual response by hypoxia, which now appears to apply to more realistic viewing situations as well as to simpler visual stimuli such as light flashes. Moreover, the present data lend further support to the finding that peripheral visual perceptual processes appear to be sensitive indicators of hypoxic stress, and may perhaps be sensitive to other stressors as well.

The results of this study clearly support the efficacy of staging as a workable technique to reduce performance impairment produced by later more severe hypoxic exposure, at least for perceptual task requirements. Despite the imperfections in this first version of the task

*ibid.

employed, the trends of impairment produced by hypoxia were clear and consistent. It cannot be determined from the data whether one variety of staging was more effective than another in this study, since the curves of Groups 2, 3, and 4 are not distinguishably different from one another. However, they all resulted in markedly better performance than that of the unstaged group. It is also interesting to note that staging effectively alleviated the physical symptoms of acute mountain sickness (headache, fatigue, cardiorespiratory changes, reduced arousal levels) as measured by other investigators during this study (Robinson, et al.). Thus, one may safely conclude that staging at altitudes of at least 1600 meters for a minimum of 2 days is an effective technique for reducing visual perceptual impairments as well as the symptoms of acute mountain sickness which have commonly been observed at higher altitudes. Furthermore, target detection appears to be a senitive indicator of perceptual impairment, and should be further explored for its practical applications in such work.

Summary

Three groups of 15 subjects each were exposed to 3 different combinations of intermediate (staging) altitudes and exposure times, and were then tested for visual target detection capability at a final altitude of 4300 meters. All groups with staging exposure performed better at altitude and had fewer symptoms of acute mountain sickness than a fourth group which went directly to 4300 meters altitude from sea level. The data showed that task factors of both viewing distance and degree of peripheral target placement significantly influenced detection time within all groups regardless of altitude exposure variations.

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Figure Captions

Figure 1. Schematic diagram illustrating target positions for 2 viewing distances based on lines of sight determined by equivalent deviation angles from the central line of sight.

Figure 2. Schematic diagram of the visual testing arrangement.

Figure 3. Mean response time for each viewing distance averaged across all target positions for Group 1 (no staging).

Figure 4. Mean response time for each viewing distance averaged across all target positions for Group 2 (staging of 4 days at 3000 meters).

Figure 5. Mean response time for each viewing distance averaged across all target positions for Group 3 (staging of 4 days at 1600 meters).

Figure 6. Mean response time for each viewing distance averaged across all target positions for Group 4 (staging of 2 days at 3000 meters).

Figure 7. Mean response time for each target position averaged across all viewing distances for Group 1 (no staging).

Figure 8. Mean response time for each target position averaged across all viewing distances for Group 2 (staging of 4 days at 3000 meters).

Figure 9. Mean response time for each target position averaged across all viewing distances for Group 3 (staging of 4 days at 1600 meters).

Figure 10. Mean response time for each target position averaged across all viewing distances for Group 4 (staging of 2 days at 3000 meters).

Table 1

Summary of the Exposure Conditions

Week	1	2	3	4	5	6	7	8	9
Group 1	200 m*					4300 m 4 days			
2		200 m					3000 m - 4 days; 4300 m - 4 days		
3			200 m			1600 m - 4 days; 4300 m - 4 days			
4				200 m				3000 m - 2 days; 4300 m - 4 days	

* m = meters altitude

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Note on the Relationship between Introversion-Extraversion, Field-Dependence-Independence and Accuracy of Visual Target Detection[1]

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As part of the overall design of the study described by Kobrick ( ) in the preceding article, Ss had completed the Maudsley Personality Inventory (Eysenck, 1959) and the Gottshaldt Hidden Shapes Test, as used in the Cattell 12 O-A Battery (Cattell, et al., 1955). The tests were administered to Ss in groups at sea level at the start of the study but were scored at the completion of the study.

Theoretical interest centered upon the interaction between the dimensions of introversion-extraversion and field-dependence-independence (Fine, 1972, 1973; Fine and Danforth, 1975) with respect to accuracy of performance on the target detection task described by Kobrick ( ) and upon the effects of hypoxia on that interaction. Based on related research (e.g., Barrett, Thornton and Cabe, 1969; Bucklin, 1971; Eysenck, 1967; Fine and Cohen, 1963; Fine and Danforth, 1975; Keister and McLaughlin, 1972), it was expected that, at sea level, field-independent Ss would be more accurate at target detection than field-dependent Ss and introverts more accurate than extraverts. Considering the two personality dimensions in interaction, it logically followed that field-dependent extraverts

should be the poorest performers. This prediction was given additional credence by Fine and Danforth (1975) who found that field-dependent extraverts were the poorest performers on the rod and frame.

No hypotheses were made regarding the effects of hypoxia on the personality-performance relationship, although research by Fine (1968) which indicated that "outgoing" personality types were less ill than introverted types at altitude suggested that the predicted superiority of introverts over extraverts at sea level might be diminished at altitude.

Ss were categorized, on the basis of median scores on both the Maudsley and Hidden Shapes Tests, as field-independent extraverts (n = 9), field-independent introverts (n = 15), field-dependent extraverts (n = 10) and field-dependent introverts (n = 15). Medians were based on cumulative distributions from a number of previous studies (Fine, 1972) and are considered to more accurately depict the population parameters than would medians based on the present sample alone, which contains a disproportionate number of field-independent Ss. The median for the introversion-extraversion dimension was between 30 and 31; that for field-dependence-independence was between 23 and 24.

Preliminary analysis indicated that there were relatively few errors in target detection at viewing distances of up to 150 feet or at either the center or 7° viewing angles under light or dark conditions at either sea level or altitude. Accordingly, only data from viewing distances greater

than 150 feet and viewing angles of 14° and 21° were used in the following analyses. Thus, at both sea level and altitude, target detection accuracy could be determined for each S on 40 trials (5 viewing distances - 175', 200', 225', 250', 275', each at four viewing angles - 14°L, 14°R, 21°L 21°R, under light and dark conditions).

Responses of all Ss within each of the four personality groups were pooled across the 40 trials for purposes of inter-group comparisons. Occasional malfunctions of equipment or unavailability of Ss for unavoidable reasons resulted in loss of some or all responses of a few Ss under certain conditions. However, no systematic bias was detectable between groups in this regard.

The results are shown in Table 1. We found that, at sea level, the field-dependent Ss generated proportionally more correct target detections than did field-dependent Ss ($X^2 = 9.61$, $P < .01$, 1 df), the introverted Ss generated proportionally more correct identifications than did the extraverted Ss ($X^2 = 18.27$, $P < .001$, 1 df) and the field-dependent extraverts were the least accurate of the four personality groups ($X^2 = 35.59$, $P < .001$, 3 df). It is evident that the significant differences found between the introvert and extravert groups and between the field-dependent and field-independent groups are attributable to the poorer accuracy of the field-dependent extravert group.

Insert Table 1 about here

The field-dependent extravert group also was found to be the least accurate of the four groups at altitude ($X^2 = 14.32$, $P < .01$, 3 df, for combined light and dark conditions). In addition, in the dark condition, there appeared to be a differential effect of altitude on accuracy of target identification which was related to personality type. Extraverts as a group seemed to improve from sea level to altitude whereas introverts either showed no change or had a decrement in performance, depending upon the specific conditions. However, since the "staged" groups (see preceding article by Kobrick) differed markedly from one another and from the control group with respect to personality composition, it was not possible to pursue these observations statistically. Such an inquiry would appear to be valuable in future studies in which personality distributions within experimental groups are matched or in which Ss serve as their own controls.

In summary, field-dependence-independence and extraversion-introversion were found to be separately and jointly related to accuracy of target detection, as predicted. In view of these results and those from previous studies (Fine, 1972, 1973; Fine and Danforth, 1975), it is apparent that the interaction between field-dependence and extraversion is of importance to understanding variability in human perception, particularly if one views those personality dimensions as reflecting fundamental underlying differences in central nervous system structure and/or function (Fine, 1972, 1973).

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Footnotes

1. This human research study, in protocol form, was reviewed and approved by the Office of the Surgeon General for the Department of the Army in accordance with Army Regulation 70-25. The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the Department of the Army or the Department of Defense.

Summary

Field-dependence-independence (Hidden Shapes Test) and extraversion-introversion (Maudsley Personality Inventory) were found to be separately and jointly related to accuracy of target detection. The major effects were attributable to the notably poorer performance of Ss characterized as field-dependent extraverts.

Table 1

Target Detection Accuracy at Sea Level and Altitude by Personality Type*

Sea Level	Field-Dependent Extravert	Field-Dependent Introvert	Field-Independent Extravert	Field-Independent Introvert
Number (%) Correct Detections	150 (41)	298 (58)	187 (56)	335 (59)
Number (%) Incorrect Detections	220 (59)	219 (42)	146 (44)	235 (41)
Altitude				
Number (%) Correct Detections	170 (51)	321 (59)	226 (65)	349 (60)
Number (%) Incorrect Detections	163 (49)	219 (41)	122 (35)	228 (40)

* Table includes only data from distances of 175', 200', 225', 250', and 275', each at 4 viewing angles under light and dark conditions (see text)

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